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BRIQUETTING IN THE BENEFICIATION OF FINE COALS

by

E. Swartzman

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of the Mining Society of Nova Scotia, Keltic Lodge, N.S., July 2-4, 1959,
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ABSTRACT

This paper presents a general review of the various methods of briquetting, with and without the aid of a binder, with special reference to the production of a suitable briquette from Nova Scotia fines for reblending with industrial coal. From the economic and technical viewpoints, either small stoker-sized briquettes made with about 4 percent asphalt in standard low pressure double-roll presses, or briquettes made without binder in high pressure double-roll presses, appear to be the most reasonable solution at present.

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INTRODUCTION

As a result of machine mining, and various mechanical methods of handling coal from producer to consumer with a view to reducing costs of production and final costs at delivery, the coal industry has had to face the problem of an increasing production of smalls and fines. Not only do the finer sizes result in a reduction in the quantity of intermediate and larger sizes which still carry a premium price, but the additional fines in the mine run and, especially the slack sizes, make them less attractive, and in some cases unacceptable, for use in many types of industrial and commercial combustion equipment fitted with grates and mechanical stokers. Furthermore, as the fines increase, problems concerned with handling, storage, freezing and cleanliness, and with discharging from bunkers when wet or frozen, become aggravated.

One basic way of dealing with the problem of increasing fines is to reduce breakage of coal to a minimum during mining and subsequent handling; this involves the development of new types of coal mining machines, based on a more intimate and accurate understanding of the fundamentals of coal fracturing. However, until such time as experimental research and engineering work result in the development of mining machinery and methods of handling coal which minimize breakage to an acceptable level, the immediate logical solution appears to be agglomeration or briquetting to make larger and more or less stable lumps out of the fines. Where the coal is very friable, briquetting may well be the only solution to reducing, to an acceptable point, the quantity of fines in the products offered to the market.

BRIQUETTING WITH BINDERS

Historical Background

Briquetting with the aid of binders, as an industrial method of beneficiating coal fines from bituminous and higher rank coals, is a relatively old art. The need for agglomerating fines, with a view to preparing a larger sized product that would more readily find a market and at the same time allow for a more equitable return on an original size of product which was depressed in value because of the difficulty in marketing it, was quite evident even in the beginning of the 19th century. The first briquetting plant was established in France in 1842, using soft coal-tar pitch as a binder. This was followed, a year later, by the introduction of hard coal-tar pitch, which, aided by heating with steam to soften and blend it with the coal fines, allowed for the preparation of coal blocks on a large scale at a profit.

In North America, with the rapid development of the oil refining industry, hard coal-tar pitch was replaced by soft petroleum asphalt which was applied in the molten state. Though hundreds of other binders have been experimented with, coal-tar pitch and petroleum asphalt are still used almost exclusively for coal briquetting.

Briquetting of coal is not a new beneficiating tool to Canadian industry. The first such industrial development recorded was that at Bankhead Collieries Limited, Bankhead, Alberta. The entire plant was designed and built by a United States firm in 1907, for the Canadian Pacific Railway, to manufacture railway, commer-

cial and household briquettes. The 2-1/2 ounce pillow-shaped briquettes were made from the screenings of very friable semi-anthracite, with coal-tar pitch as binder, using the so-called standard low pressure roll-presses. These, like the modern ones, consist of a pair of horizontally arranged rolls (revolving in opposite directions) whose faces are provided with suitably shaped pockets, within which the compacts or briquettes are formed by compression.

The first recorded manufacture of briquettes in the Maritimes was in the two plants of the Colonial Coal Company, Sydney, N.S., erected in 1916. The machinery was imported from England. The coal and hard coal-tar pitch were pulverized, mixed, fluxed with steam, and pressed in Belgian roll-presses, making egg-shaped briquettes.

Petroleum asphalt as a binder was probably first employed in Canada at a plant established in 1918 by the Anthracite Briquette Company, in Toronto, using the Gamble process to briquette imported anthracite fines. In this process the binder was essentially sulphite liquor (calcium lignosulphonate), with asphalt added to produce a water-proofing effect. As the briquettes had to be thermally dried to yield a product of sufficient strength for handling, the sulphite liquor was gradually reduced and the asphalt increased, until only asphalt was used. This plant closed down in 1928.

In 1925, the Canmore Coal Company, Canmore, Alberta, installed a plant with a roll-press to briquette the fines resulting from screening the coal prepared for railway use. These anthracitic to low-volatile-bituminous coals were briquetted with about 7 percent petroleum asphalt binder to make 2-ounce household briquettes. In 1947 the plant was enlarged. It is still in operation, making various types of briquettes. Several other plants were established in Western Canada, but in recent

years, due to the replacement of coal burning locomotives by oil-burners and diesels, and because of the competition of oil in the commercial and household markets, a number of the plants have been closed down.

Railway Briquettes

Several of the plants established in Western Canada, primarily for preparing low binder content briquettes to be used in admixture with screened coal as railway fuel, are still in operation, although to a decreasing extent as coal is being replaced by oil.

Years of experience and test work by the major Canadian railways indicated the superiority of sized coal and briquettes to mine-run coal, in locomotives. Reduction in consumption of fuel has been shown to vary with the tonnage being hauled, but, on a total fuel consumption basis, when using briquettes an over-all average reduction of 20 percent may be expected¹ in comparison with 4 to 14 percent estimated fuel savings when using sized coal.

As the proportion of fines (0 x 1/4 in.) in the mine-run product of most Canadian bituminous coals is fairly high (up to 60 percent in some Western coals), it would not be economically feasible for the mines to supply a sized coal. Briquetting of the fines, to produce about 2-ounce ovoids to be remixed with the screened coal, has been found to be the most economical method of eliminating the fines problem. The standards set by the Canadian railways were such that briquettes of an acceptable quality were prepared with a maximum of 4 percent petroleum asphalt binder. In making railway briquettes there would appear to be no great advantage in using more than 4 percent asphalt, as the amount of breakage which occurs in the stoker remains fairly constant when briquettes are prepared with petroleum asphalt

binder ranging from 4 to 7 percent; tests¹ indicated that, on the average, 2 to 2 1/2 inch briquettes break down as follows: On 2 in. - 5%; 2 x 1/2 in. - 50%, 1/2 x 1/4 in. - 13%, and 0 x 1/4 in. - 32%.

Stoker Sized Briquettes

In addition to the above, consideration has also been given to the briquetting of coal fines for the production of fuel suitable to be used alone or in admixture with sized coals, for household, commercial and industrial stokers. Initial experiments at the Fuels Division laboratories indicated the possibility of making small (1 x 3/4 x 1/2 in.) briquettes, weighing 4 to 6 gm, equivalent in quality to sized stoker coal. The briquettes, as in the case of those made for locomotive use, do not require great strength. About 4 percent asphalt binder is sufficient to produce an agglomerate that will not deteriorate or segregate too seriously on handling when in admixture with sized coal, and that will be absolutely waterproof.

As a direct result of this experimental work, briquettes of this type have been manufactured since 1955, from medium volatile bituminous coal fines, by the Coleman Collieries Limited, in Alberta. The 1 x 1 x 5/8 in. pillow-shaped briquettes are remixed to the extent of 15 to 25 percent with 1/4 x 1-1/4 in. stoker coal.

In 1953, stoker-sized briquettes were made experimentally from the Franklin Mine coal of the Sydney Mines area, N.S., and Four Star Collieries coal of the Broughton area, N.S., with a view to testing them in a domestic underfeed stoker. The physical properties of these small almond-shaped briquettes, made with about 4 percent petroleum asphalt binder, are shown in Table 1, in comparison with commercial briquettes manufactured in Western Canada.

TABLE 1

Physical Qualities of Experimental Stoker Briquettes

	Franklin Briquettes	Four Star Briquettes	Commercial Stoker Briquettes
Compressive Strength			
Briquettes broke at...ga	2648	3362	6124
Tumbler Test ⁽¹⁾			
Stability%	87.2*	82.8*	54.1**
Abradability(-10 mesh)%	10.2	15.1	33.2

* Percent retained on 1/2" screen.

** Percent retained on 3/4" screen, because briquette larger.

(1) 1000 gm briquette tumbled in jar mill for 1/2 hr at 40 rpm.

The experimental Nova Scotia briquettes compare very favourably with the commercial stoker briquettes from Western Canada.

It is of interest to note that, when low ash fusion coal which gives clinker trouble is used, the admixture of briquette made from the same coal tends to alleviate the condition. Tests with mixtures of Broughton coal and briquettes showed that, as the proportion of briquettes to stoker coal increased, the resultant clinker weakened. It would appear that, as the briquettes burn away, a skeletal lattice work of ash remains which does not coalesce readily and form a solid clinker, but tends to remain soft and spongy. This characteristic is a definite advantage when considering automatic ash removal stokers.

Recent experiments² with Nova Scotia coal fines from the Sydney area also clearly indicate that, with the addition of about 4 percent of a suitable petroleum asphalt binder, stoker-sized briquettes

of a satisfactory quality can be readily prepared in standard roll-presses. Table 2 presents data on the physical properties of such experimental Sydney area coal fines briquettes, in comparison with the Western commercial briquette being presently marketed.

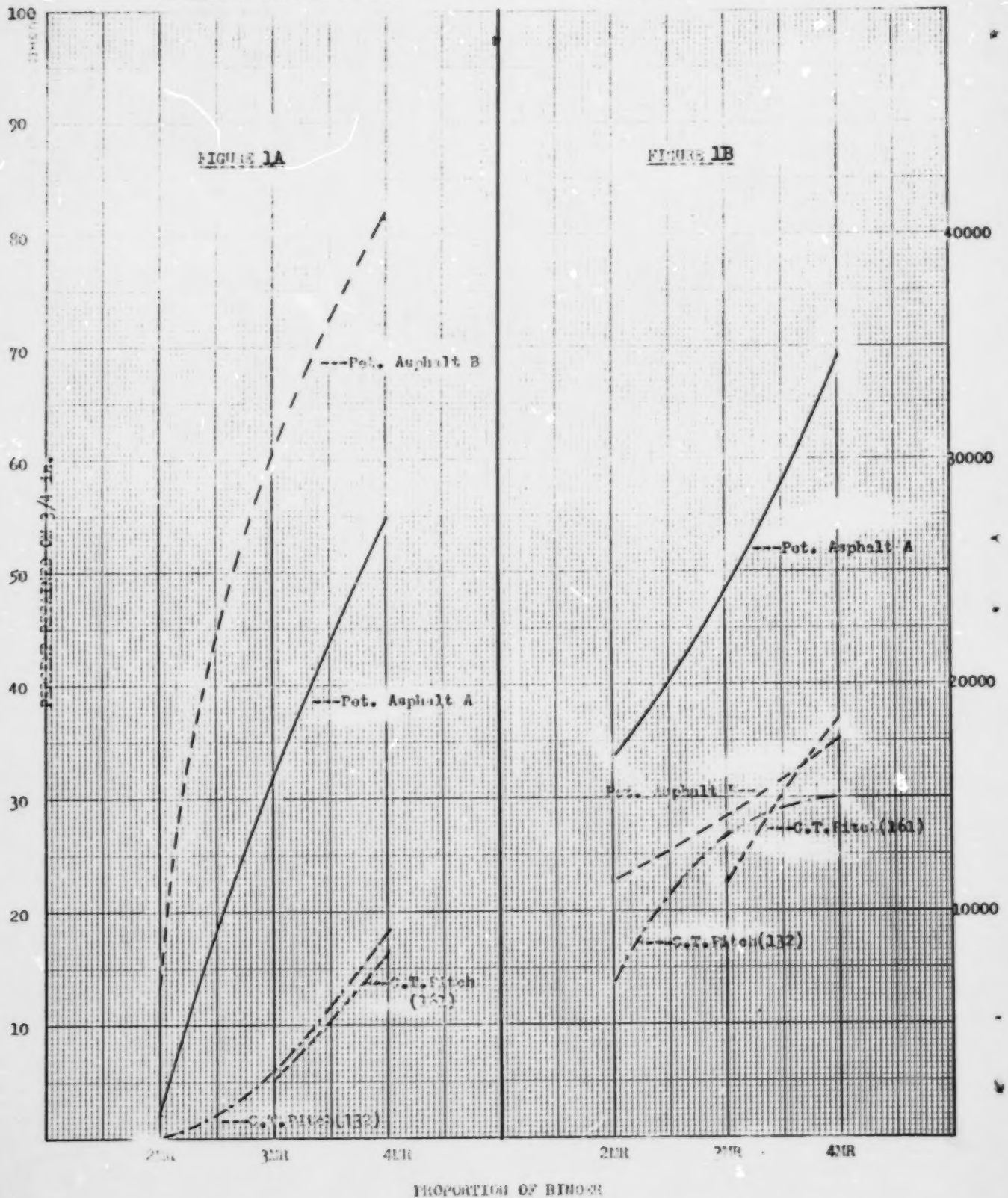
TABLE 2

Physical Qualities of Experimental Stoker Briquettes

	Sydney Area Briquette	Western Commercial Stoker Briquette
Compressive Strength		
Briquette broke at gm	17,623	6124
Tumbler Test*		
Stability (+3/4").....%	81.4	37.1
Abradability(-10 mesh).%	18.6	47.4

* 1000-gm briquette tumbled in jar mill for 1 hr at 40 rpm.

In the series of tests conducted, two types of petroleum asphalt having similar softening points (137-145°F R&B) and penetrations (14-19 at 77°F) were used. However, asphalt A was very ductile at room temperature, whereas asphalt B, a standard briquetting cracking-coil asphalt made in Western Canada, exhibited very low ductility. In addition, two coal tar pitches, one with a softening point of 132°F and the other, 161°F, were also used. The physical qualities of the resultant briquettes, using 2, 3, and 4 MR (parts of binder per 100 parts of coal) of the binders, as indicated by the Tumbler Stability and Compressive Strength, are shown in Figures 1A and 1B.



Although in all cases the strength of the briquettes increased with the quantity of binder, the degree of increase varied with the binder, petroleum asphalt B showing the best results. For reasons not obvious at present, the coal tar pitches yielded the poorest briquettes, of a quality that would be unsatisfactory for the purpose. The ductile Asphalt A resulted in briquettes that were less stable to tumbling than those from Asphalt B with low ductility. The high compressive strength of the briquettes made with the ductile asphalt was misleading, as under compression they squatted slowly, instead of retaining their form and then sharply breaking at maximum load as a good briquette should.

Thus, it is not enough merely to specify the softening point and penetration for an asphalt of suitable quality for briquetting. Low ductility is also a necessary requirement. Furthermore, it is well established that asphalts made from aromatic crudes are superior to those made from the paraffinic types.

All existing commercial briquetting processes for bituminous and higher rank coals, employing binder, use the standard low-pressure roll presses. Recently at GHERCHAR*, Charbonnier³ and co-workers have demonstrated that substantial reductions in binder can be effected, especially in cases where one has to deal with coals that are high in surface moisture, by the use of horizontal open-mould extrusion presses of the type used extensively in Germany for the binderless briquetting of lignite. The experimental press used was designed for 1 tph at 100 rpm and was fitted with a trapezoidal mould. Compared with the standard roll-type press (externally tangential roll presses), which

* Centre d'Etudes et Recherches des Charbonnages de France.

has an estimated developed pressure of about 2000 psi and a retention time of about 0.1 second, the open-mould press at pressures of up to 8000 psi and a retention time of up to 7 seconds permitted substantial savings in binder. With $0 \times 1/4$ in. bituminous coal, the open-mould press gave good commercial (household) briquettes with 3.8 percent coal tar pitch instead of the 7 percent required with the roll presses. The best results, however, were obtained by crushing the coal finer to pass 1 mm (18 U.S. mesh). Good commercial briquettes were made with coal ground finer, as above, using 3.5 mixing ratio (under 3.4 percent) of standard coal tar pitch (about 175°F Softening Point-Ring and Ball Method) under a pressure of about 4000 psi. Under these conditions, mixes containing up to 8 percent surface moisture were readily briquetted. Energy consumption was about 28 kwh/ton in comparison with about 3 kwh/ton for standard roll presses. Thus, higher pressures and longer compression time are the main sources of the improvement.

It was estimated that a 6 tph unit driven by a 250 hp motor would, in 1954, cost about 16 million French francs (about \$38,100 U.S. funds at 420 francs per dollar), inclusive of motor and installation. A 30 tph roll press, with motor, reducer, installation, etc., cost at that time about 11.5 million French francs; that is, about \$27,380 in U.S. funds.

If one assumed a 60 tph plant (1200 tons/day or 360,000 tons/yr), with power at 1.43 cents per kwh and pitch at approximately \$32.40 per ton, the costs of the open-mould press briquettes in comparison with those made in roll presses have been estimated as shown in Table 3. For these calculations it was also assumed that the roll press requires 3 kwh of power per ton of briquettes, against 28 kwh/ton for the open-mould press; and that with the roll press, 7% (70 kg/ton), and with

the open-mould press, 4% (40 kg/ton), of pitch binder is used.

TABLE 3
Estimated Cost of Briquetting: Roll Press Vs. Open-Mould Presses

	<u>Roll Press</u>		<u>Open-Mould Press</u>	
	<u>France</u>	<u>Dollars</u>	<u>France</u>	<u>Dollars</u>
No. of presses required	2 of 30 tph		10 of 6 tph	
Unit cost installed	11.5 million		16 million	
Total cost of presses	23 million		160 million	
Customs duties, etc.	-		40 million	
Depreciation, including financial charges @ 13%	3 million		26 million	
Capital cost per ton of briquettes	8	0.017	72	0.171
<u>Operating Costs</u>				
Cost of pitch per ton of briquettes	1,050	2.500	600	1.429
Cost of power	18	0.043	168	0.400
Cost of labour (1 man for 2 presses at 250 f/hr)	4	0.010	20	0.048
Total processing cost	1,080	2.570	860	2.048

Thus, it is seen that the saving in pitch consumption in using the much more expensive extrusion presses yields an overall saving of 220 f., that is, about 52 cents per ton of briquettes. Even if the labour costs are tripled to meet Canadian conditions, the difference will still be over 40 cents per ton in favour of the open-mould presses. There appears to be no reason why the same results cannot be obtained with petroleum asphalt. Thus, in accordance with the

CHERCHAR results, it would seem possible that a lower cost, very strong briquette can be made with relatively moist coal, using not more than 3.5 percent binder. This question of moisture is important, as with standard roll presses the maximum moisture content permissible is about 3 percent, beyond which the briquettes begin to get progressively weaker.

If for industrial purposes a weaker briquette were considered satisfactory, then it is possible that such a briquette could be made with about 2 to 2.5 percent asphalt in the open-mould press, instead of 4 percent as required with the roll press. Using the same values as in the estimate shown above, the saving in asphalt would be between 54 cents (at 2-1/2 percent) and 72 cents (at 2 percent).

Such a process is thus worth considering, even though the capital cost of the plant may be substantially higher than a roll press. In addition to savings effected in binder, wetter coal can be processed, and, because less bond is employed, additional smoke production is held down to a minimum.

BINDERLESS BRIQUETTING

Binderless briquetting began with the briquetting of brown coal in Germany, around 1870, and it has since become the largest briquetting industry in the world. Although these briquettes are made from fine coal, the process cannot be considered one which was developed to beneficiate fine materials, but rather to upgrade the raw mine-run coal as a whole. The brown coal as mined contains over 50 percent moisture, is low in calorific value, and breaks down readily on weathering. The processing whereby this coal is crushed, dried, and briquetted results in a product which is low and stable in moisture content, is

appreciably higher in calorific value, and stores readily without serious degradation.

Most of the binderless brown coal briquettes are made in horizontal extrusion presses with reciprocating pressure plungers developing pressures up to about 17,000 psi.

Ring-roll presses were later specially designed in Europe for briquetting brown coal without a binder. The Krupp-Herglitz press, developed independently of, but at the same time as, the Apfelbeck press, has been used extensively in Germany and neighbouring countries since 1934 to produce an agglomerate for carbonization or gasification. In this machine, the ring, a heavy steel forging weighing about 16 tons, is carried on two rollers, one of which is directly coupled through a reduction gear to a variable-speed motor. The ring rotates by friction at 1 to 7 rpm. The roll, the periphery of which has a circumferential rib, is carried eccentrically within the ring in heavy bearings, connected to a pair of heavy tie-bars which are either hydraulically or spring loaded, and so adjusted that the rib on the roll enters a groove in the ring, dividing the groove into two channels.

The basic principle of the ring-roll press is the rather slow application of relatively high pressures, which permits adequate degassing of the fine materials. Pressures developed have been estimated up to about 35,000 psi; the narrower the briquette stream the higher the pressure attained, but the lower is the throughput.

In view of the success of the binderless briquetting of brown coals, many attempts have been made to apply this idea to higher rank coals, especially because of the substantial saving in the cost of the binder and the possibility of making a product whose smoke-producing characteristics would not be aggravated by the addition of

asphalts or pitches.

Generally, it should be possible to effect the cohesion of coal particles to form solid agglomerates, either by subjecting the coal to a very high pressure at normal temperatures, or by heating the coal, before it enters the briquetting press, to a temperature at or below the softening point of the coal so that a low (about 2000 psi) or slightly elevated pressure should suffice to form the agglomerate. As a third means, both of these measures may be combined.

Using High Pressures at Normal Temperatures

The first process for briquetting higher rank coals, other than brown coal or lignites, without a binder using only high pressure was developed by E.C. Evans who, in 1914, with E. R. Sutcliffe, under the company name of Pure Coal Briquettes Limited (D.R.P.* (German) 320,794/1914), erected a plant in England. The process consisted of briquetting a moistened mixture of coking coal with about 20 to 25 percent coke breeze, without binder, at about 20,000 psi in a specially developed ovoid press. However, the briquettes had to be carbonized at from 600 to 1000°C, to give them strength and make them smokeless. Although expensive, because fine grinding was required, it was concluded that most coking coals briquetted cold with an admixture of coke as a diluent to reduce swelling and plasticity, would result in an excellent fuel suitable for metallurgical purposes after carbonization.⁴ Since 1922 nothing further has been heard of the plant or process, and it is assumed that, because of economic or technical reasons or both, the process has not been successful.

* Deutsches Reich Patent.

In 1934, when the Krupp and Lurgi companies became interested in the Herglotz ring-roll press, the adaptation of the process to higher rank coals was studied. After the end of World War II, Dr. E.C.R. Spooner, on behalf of the British Ministry of Fuel and Power,⁵ reported on the German experience with the Krupp-Herglotz presses. It was observed that the briquetting of bituminous coal without a binder involves fine grinding and the use of high pressures. Fine grinding is costly, and, to attain high pressure with ring-roll presses, it is necessary to reduce the width of the briquette stream and thus the output of the press. Furthermore, not all coals are susceptible to briquetting without a binder, even under these extreme conditions, and not all are entirely weatherproof. It has been shown that the addition of 2-3 percent of coal-tar pitch or asphalt permits the use of coarser material and lower pressures.⁶ The problem, then, is economic rather than technical, and is concerned with balancing the advantages of reduced fine grinding costs, lower power consumption, and greater output, against the cost of using a small quantity of binder in producing household or commercial briquettes. However, it is doubtful that the higher capital cost of ring-roll presses, as compared with low-pressure, ovoid-producing presses, would be offset by the possible saving in binder. The fact is that, to date, ring-roll presses have not replaced the standard roll-press in the briquetting of bituminous coal, even with the aid of a binder.

Various factors influencing the briquetting of coal without binder have recently been thoroughly studied at the Central Fuel Research Institute, India.⁷ In these laboratory experiments a cylindrical die, 1.27 in. in diameter and 1 in. high, was used and a known volume of coal was hydraulically compressed to any desired pressure,

which was maintained for 1 min and then gradually released. As a result of these experiments, it was concluded that the compressive strength of briquettes "obtained from coals of different rank -- is largely influenced by briquetting pressure, degree of comminution, and moisture content, the extent of the influence depending on the rank of the coal". The "maximum strength is obtained when briquetting at a moisture content corresponding to that of the air-dried moisture (at 40°C and 60% relative humidity)" of the coal and when crushed to pass a 72 mesh (B.S.S.) screen. Under these optimum conditions the order of variation of strength for coals of different rank was found to be as follows: medium rank < high rank < low rank. Even at pressures as high as 35,000 psi, briquettes of minimum strength were made from coals with 81 to 83 percent carbon on the dry mineral matter free basis. These include the lower rank High Volatile A and High Volatile B bituminous coals. Coals lower and higher in carbon content showed an increase in strength, the rate of increase being greater in the direction of the lower rank coals, with a maximum at the lignites.

In Table 4 are shown the carbon content and rank of typical coals from various areas in Nova Scotia.

If the 81 to 83 percent carbon limits hold for Canadian coals as well as for Indian coals, then the coal from the Joggins and Broughton areas should be expected to yield the poorest binderless briquettes, whereas those from the Sydney Mines, Sydney and Thorburn areas should result in agglomerates with greater strength when formed at the same pressures. It would appear, from this work, that a pressure of at least 10,000 psi, and probably closer to 15,000 psi, would be required to yield briquettes of suitable strength.

TABLE 4
Carbon Content and Rank of Certain N.S. Coals

Area in Nova Scotia	Carbon - % (dry mineral matter free)	Rank ASTM
Ste. Rose	79.1	High Vol. C Bit.
Joggins	82.2	" " A "
Broughton	82.3	" " " "
Sydney Mines	84.7	" " " "
Sydney	85.1	" " " "
Thorburn	85.3	" " " "

It is of importance to note that the authors indicate that, although coals between 81 to 83 percent carbon are relatively the most difficult to briquette, the strength of the briquettes can be appreciably increased by briquetting them at temperatures from 100 to 300°C.

As the residence time in these experiments was 1 minute, it is fairly safe to assume that the short residence time of less than a second, as normally obtained in a roll press, would yield briquettes of much lower strength. Furthermore, the rapid pressure release experienced in a roll press would, in most if not all cases, result in an expansion of the compacts. It thus appears obvious that extrusion or plunger presses with a longer residence time and slower pressure release would be more suitable to yield a product of optimum quality.

In this regard, it is of interest to note the recent research work in the United Kingdom at the Coal Research Establishment of the National Coal Board. Although little detailed data has been released to date, the 1957 "Summary of Research Work" gives the following infor-

mation on the so-called 'Shape' process for binderless briquetting. This process involves the use of a specially designed plunger press in which both shear and direct pressure are utilized. Laboratory investigation has shown that binderless briquettes made from so-called low rank coals, High Volatile A bituminous and lower, such as those in Nova Scotia, "would tolerate large amounts of shear strain, whereas high-rank (medium and low volatile bituminous) briquettes soon cracked". "However, for a given pressure and (small) shear the high-rank briquettes were stronger than the low-rank, and both were stronger than briquettes made by simple pressing, even at very high pressures". In studying the 'Shape' briquetting of low rank bituminous coals, it was found that "briquetting at temperatures around 100°C increases the strength of the briquettes". This agrees with what the Central Fuel Research Institute of India reported. It is also of importance to note that oxidizing the lower rank coals reduces the strength of the briquettes.

Furthermore, investigations by the National Coal Board (United Kingdom) and the Central Fuel Research Institute (India) agree as to the weather resistance of the binderless briquettes, which was found to decrease with increasing oxygen content, that is, with decreasing rank of the coal.

In addition to the plunger press, the National Coal Board have developed an expansion press which embodies the principle of effecting a shear strain during extrusion through a die. Although it has been shown that the operating conditions in such a press are much more critical for bituminous than for brown coal, the mechanism appears to be simpler and more robust than the plunger press, and has thus been further developed to the pilot plant stage.

All of the preceding investigations indicate that to produce binderless briquettes equivalent in strength to household briquettes made with about 7% of either coal tar pitch or asphalt as a binder, high

pressure plunger or extrusion presses would be required, and that improved quality, especially of the lower-rank bituminous briquettes, might be attained by preheating the coal to about 100°C.

However, a briquette of lower strength, which might be suitable for remixing with slack, stoker or mine-run to reduce fines, might be produced in a modified double-roll press.

In recent years, Komarek-Creaves and Company in the United States have spent considerable time in developing a modification of the standard roll press, and suitable necessary auxiliary equipment, which would allow for the briquetting of bituminous coals at relatively high pressures and normal temperatures. The experiments indicated that fine sized bituminous coal, suitably de-aerated either by precompression in high pressure "flaking rolls" or in specially designed (helical) pressure feeders, can be briquetted without binder in a roll press which allows for the development of high pressures. The presses, one type of which is shown in Figure 2, are of low capacity, and it has been found that not all coals are equally amenable to briquetting in this manner. Low volatile bituminous coals appear to be more susceptible to this processing than high volatile bituminous coals. This agrees with the conclusions of the recent work conducted in the United Kingdom and India, as indicated previously. However, the lower rank bituminous coals would appear to yield a briquette that might be strong enough for remixing with stoker, slack or mine run coal. A recent test on a Nova Scotia high volatile A bituminous coal yielded small almond-shaped briquettes with physical properties comparing favourably with slightly larger stoker-sized briquettes made in standard roll-presses commercially or experimentally, using 4 percent asphalt binder. Table 5 presents the comparative quality of the briquettes.

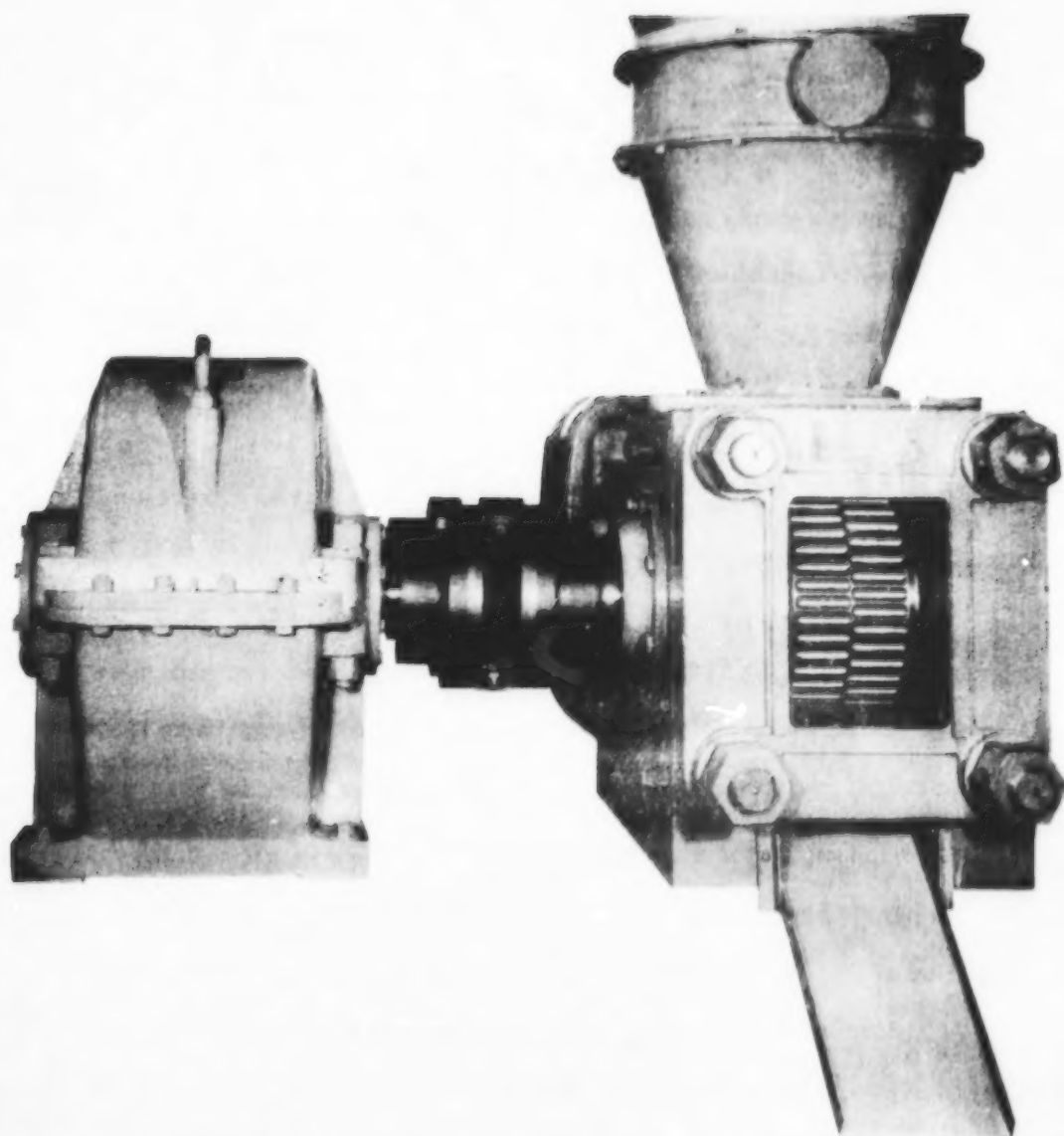


FIGURE 2 - KOMAREK-GREAVES HIGH PRESSURE
DOUBLE ROLL PRESS

TABLE 5

Binderless Briquettes Vs. Asphalt-Bonded Stoker Briquettes

	Binderless N.S. Coal (1)	<u>With 4 % Petroleum Asphalt</u>	
		N.S. Coal (1)	Commercial (2)
Tumbler Test*			
Stability.....%	68.1(a)	81.4(b)	37.1(b)
Abradability(-10 mesh)%	24.3	18.6	47.4
Compressive Strength			
Briquettes broke at, gm	6124	17,623	13,438

(1) Same high volatile bituminous coal.

(2) Made from medium volatile coal in Alberta.

* 1000 gm rotated for 1 hr at 40 rpm.

(a) + 1/2 in.

(b) + 3/4 in.

The binderless briquettes were quite weatherproof. Soaking them in water for a week reduced their strength, but they did not disintegrate.

Although experiments have not yet been conducted in the above-mentioned high-pressure roll-press with coal at slightly elevated temperatures, there would appear to be no doubt, from the results of experiments conducted in the U.K. and India, that preheating the coal to 100°C or somewhat higher would improve the strength of the briquettes.

Hot Briquetting

All hot briquetting processes for bituminous coals depend on the plasticity or fluidity stage developed during heating at temperatures

below 500°C.

In Belgium, in 1931, Hardy⁸ attempted to briquette bituminous coking coal in a roll-press with the coal preheated to between 350° and 450°C. In 1952 Darnont⁹ stated that the process, based on the plasticization of coal dust by application of heat, depends on the coal being kept in motion during heating in order to ensure a quick and homogeneous rise of temperature while preventing agglutination. To date this process has been unsuccessful because of mechanical difficulties and because of difficulty in controlling the physical state of the coal at the critical plastic stage while transferring it from a retort to the press.

A process for briquetting bituminous coal,¹⁰ in which the coal is thermally treated prior to briquetting, was also developed in France. This process consisted of a two-stage carbonizing oven, one stage above the other, for the thermal treatment of the coal. In the upper zone, the coal resting on a belt conveyor was subjected to a temperature of 150 to 200°C by hot combustion gases, to expel the water. Then the coal was scraped over an indirectly heated steel floor and deposited on a second conveyor in the lower half of the oven, and again distributed and scraped over a heated hearth and raised to a temperature at which the coal attained the requisite degree of plasticity. After leaving the hearth the plastic mass was fed immediately into presses arranged under the oven. In view of the extensive destructive distillation, weakly coking coals were not recommended.

No further information is available on the commercial development of the process, and it is assumed that, for the reasons mentioned in discussing the Hardy process, this French process did not meet with success.

Quite recently, in their drive to develop methods for the production of more or less smokeless fuel, especially for the household trade, the Central Research Establishment of the National Coal Board (U. K.) has re-examined the possibility of making use of plasticity developed in coking coal at somewhat elevated temperatures.^{11,12} Some rather interesting laboratory experiments indicated that small additions of pitch (about 2% to 4%) to coal broadened the temperature range through which the coal remained plastic, by 100°C or more, by lowering the softening temperature. This tendency decreased with a decrease in rank, but where the plastic range was substantially increased it indicated the possibility of overcoming the natural critical character of the plastic state and thus alleviating the difficulties formerly experienced. The coking coal could be preheated externally with the pitch to a temperature range which could readily be maintained for a sufficient period to allow mixing with larger quantities of coke breeze or char, anthracitic coal, or low volatile non-smoky non-coking steam coal. The plastic coal mass would act as the bond, and the briquetting could be effected in a standard roll-press maintained at ambient temperature. This process had been developed to the pilot plant stage in 1958 and experiments were in progress to determine, from both the technical and the economic standpoints, the feasibility of a commercial operation.

However, as the high volatile bituminous coals of Nova Scotia are amongst those coals whose plasticity characteristics are little affected by the addition of pitch, as indicated by experiments conducted at the Fuels Division, this process would not appear to be applicable to these coals.

Experiments by the National Coal Board have also indicated

that removal of only a small proportion of volatile matter from high volatile coal by passing air preheated to about 400°C through a fluidized bed of fine coal will result in a char or residue which is practically smokeless. This char, it is claimed, may be briquetted with a binder made of coal and pitch as noted above.

The Dutch State Mines have also been conducting experiments on the production of a smokeless binderless briquette based on the plastic characteristics of coking coal. The pilot plant at the Maurits washery employs a double-roll press, larger than usual, being about 55 in. in diameter. With such a press, fitted with special heavy springs accompanied by heavy feeding, it is claimed that pressures of about 9,000 psi are attained. In order to keep swelling and expansion of the briquettes to a minimum, about 70 percent of anthracite is mixed with coking coal (15 to 30 percent volatile matter) plasticized at 400°C. The hot mix is conveyed pneumatically by hot gases and degassed in cyclones prior to feeding to the press. The major difficulties experienced are in temperature control, especially at the critical plastic stage of the coal, where the plasticity of the coking coal changes rapidly over a short temperature range with final solidification taking place very quickly within only a few degrees.

Both the fluidizing and briquetting processes require little ground coal. In view of this, and because either a two- or a three-stage process is required, the economics of such processes to produce nearly smokeless fuel would have to be very carefully examined. Under Canadian conditions it is very doubtful that they would yield a product that would be economically competitive. For production of an industrial briquette the process would undoubtedly be so expensive as to be completely ruled out.

CONCLUDING REMARKS

A general survey of the various methods of briquetting, with and without the aid of a binder, indicates that, in so far as the production of a suitable briquette for reblending with industrial coal is concerned, only two methods appear to be technically and economically feasible under present Canadian conditions. One is to produce briquettes with about 4 percent asphalt binder. The other is to use the simplest binderless process whereby more-finely-ground, de-aerated, and possibly precompressed coal is briquetted at normal temperatures in a double-roll press that permits the attainment of relatively high pressures. A slight preheating to 100-150°C would probably improve such a briquette, especially in the case of high volatile bituminous coals such as those produced in the Sydney area of Nova Scotia.

'Hot briquetting', which is dependent on the development of plasticity in the coal at about 400°C, is still in the experimental stage. Temperature control and rapid transfer of coal while it is plastic have continuously presented difficulties, both technical and mechanical, which so far have not been satisfactorily solved. Furthermore, it is apparent that in most cases, depending on the characteristics of the coal, varying quantities of inert materials such as anthracitic coals, cokes, and chars must be added to prevent undue swelling and expansion of the briquette. Even if hot briquetting were successfully developed to the commercial stage, it is possible that such a two- or three-stage process would not be economic under present Canadian market conditions.

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